METHOD FOR POSITIONING OF WIRELESS MEDICAL DEVICES WITH SHORT-RANGE RADIO FREQUENCY TECHNOLOGY

DESCRIPTION

The following relates to the medical arts. It finds particular application in tracking equipment and personnel in hospitals and other medical facilities, and will be described with particular reference thereto. More generally, it finds application in tracking medical equipment, wireless medical sensor arrays, medical personnel wearing or carrying cellular telephones, personal data assistants, short-range wireless-equipped identification tags, and other wireless communication devices, and other mobile devices having short-range wireless connections in medical facility settings.

Hospitals and other medical facilities are rapidly moving toward wireless networking of medical diagnostic devices, medical treatment devices, and the like. Wireless networking enables rapid transmission of data to a nurses' station, floor monitor, or other central monitoring location, reduces the number of wires and cables in patients' rooms, and allows rapid hookup of devices to the medical facility network.

Additionally, it has been recognized that wireless networking provides convenient device tracking. For example, in the context of an IEEE 802.11 wireless hospital network infrastructure, the location of roaming network devices is already largely determined based on which wireless access point has the strongest communication link(s) with the roaming device. Existing network-infrastructure based tracking systems utilize and refine this built-in network tracking capability to track wireless devices that are compatible with the deployed wireless network infrastructure. Network tracking enables medical personnel to rapidly locate mobile wireless networked medical equipment, which saves time and manpower. In emergency medical situations the ability to rapidly locate networked medical equipment can save lives.

These existing network tracking systems are limited to tracking wireless devices of their specific wireless technology. Local wireless devices employing Bluetooth, ZigBee, or other wireless technologies that are not network-compatible are not tracked. Such local wireless technologies are commonly used for short-range communication. For example, Bluetooth enabled cellular telephones, personal data assistants (PDA's), and the like are carried by many medical personnel. The Bluetooth connectivity enables these devices to

communicate with the owner's personal computer or with other devices located in the same room or nearby. Bluetooth connections are also used to wirelessly connect medical probes, wireless vital signs sensor arrays, or the like with associated monitor devices. Bluetooth, ZigBee, and other local wireless links are generally limited to about ten meters or less, and generally cannot connect with the 802.11 wireless hospital network.

The following contemplates improved apparatuses and methods that overcome the aforementioned limitations and others.

According to one aspect, a tracking method is provided for tracking a local wireless device in a medical facility having a medical facility network. The local wireless device, which is not connected with the medical facility network, is detected based on local wireless communication between the local wireless device and at least one nearby network device that is connected with the medical facility network. A location of the local wireless device within the medical facility is estimated based on the local wireless communication and information indicative of a location of the at least one nearby network device.

According to another aspect, a tracking system is disclosed for tracking a local wireless device in a medical facility having a medical facility network. A means is provided for detecting the local wireless device, which is not connected with the medical facility network, based on local wireless communication between the local wireless device and at least one nearby network device that is connected with the medical facility network. A means is provided for estimating a location of the local wireless device within the medical facility based on the local wireless communication and information indicative of a location of the at least one nearby network device.

One advantage resides in improved tracking for non-networked equipment, devices, personnel, and other items in a medical facility.

Another advantage resides in providing tracking of non-networked items in a medical facility without requiring additional communication hardware.

Yet another advantage resides in providing integrated tracking of both networked and non-networked items in a medical facility.

Numerous additional advantages and benefits will become apparent to those of ordinary skill in the art upon reading the following detailed description.

The invention may take form in various components and arrangements of components, and in various process operations and arrangements of process operations. The drawings are only for the purpose of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 diagrammatically shows a tracking system for a hospital facility capable of tracking both networked and non-networked devices.

FIGURE 2 diagrammatically shows connections between the hospital facility network and network devices, and local wireless communication between wireless network devices and local wireless devices not connected with the hospital facility network.

FIGURE 3 diagrammatically illustrates estimating the location of a local wireless device not connected with the network based on signal strength of the local wireless communication.

FIGURE 4 shows a block diagram of a client program for detecting local wireless devices that is installed on each network device capable of local non-network wireless communication.

An illustrated tracking system is described with reference to FIGURE 1, which shows a diagrammatic block diagram of the system, and with reference to FIGURE 2, which illustrates example components of the medical facility network, example wireless network devices, and example local wireless devices. The hospital network includes a local area network **10** that wirelessly communicates with wireless network devices **12**, **14**, **16**, **18**. For example, as shown in FIGURE 2, the wireless network devices may include a vital signs monitoring station **12**, a intravenous (IV) injection flow controller **14**, a patients' monitor at a nurses' station **16**, a vital signs transducer **18** carried by an ambulating patient, and so forth. The illustrated wireless network devices **12**, **14**, **16**, **18** are examples, and other devices can be similarly wirelessly connected with the local area network **10**.

The local area network **10** typically includes a local area network server **20** and a plurality of wireless network access points **22**, **24** distributed through the medical facility and connected with the local area network server **20** by wired Ethernet cables **26**, **28**. Alternatively, a Token Ring or another wired network connection can be employed. The

network access points **22**, **24** are distributed throughout the medical facility to provide substantially complete wireless network coverage for the facility, so that wireless network devices can communicate with the network **10** from substantially anywhere in the medical facility. Although not shown, in some networks wireless access extension points are provided which wirelessly communicate with one of the wired network access points **22**, **24** to provide extended network area coverage.

Network devices such as the vital signs monitoring station **12**, the IV flow controller **14**, and the nurses' station monitor **16** wirelessly communicate with the nearest or most strongly wirelessly coupled network access points **22**, **24** in order to wirelessly connect with the medical facility network **10**. Additionally or alternatively, one or more software access points can be employed. For example, a computer **30** connected with the local area network server **20** by wired Ethernet cable **32** includes a software access point implemented by a wireless card (not shown) installed in the computer **30** and suitable software. Network devices such as the vital signs transducer **18** may wirelessly connect with the software access point embodied by the computer **30** in order to wirelessly connect with the medical facility network **10**.

The wireless network connections are indicated in FIGURES 1 and 2 by jagged connectors drawn using solid lines, such as the example labeled connector **36** connecting the vital signs monitor station **12** with the access point **22** of the medical facility network **10**. (The remaining wireless network connections are similarly indicated by solid-line jagged connectors, but are not labeled with reference numbers in FIGURES 1 and 2). In some embodiments, the wireless network communication comports with an IEEE 802.11 local area network protocol; however, other wireless local area network protocols can be employed.

Some of the wireless network devices are roaming network devices. For example, the ambulatory vital signs transducer **18** moves frequently as the ambulatory patient roams the halls of the medical facility, and the IV flow controller **14** is frequently moved from room to room. Other wireless devices are less frequently roaming or may even be substantially stationary. For example, the vital signs monitor station **12** may generally stay in the same patient's room for several days, and the nurses' station monitor **16** in some medical facilities may not move for years. Network devices which are not wireless, such as the computer **30**, generally move infrequently or not at all.

A network devices tracking system **38** tracks the mobile or potentially mobile wireless network devices **12**, **14**, **16**, **18**. The network devices tracking system **38** is typically a software program or module executing on the local area network server **20**; however, another computer or other digital processing hardware can embody the network devices tracking system **38**.

As a roaming wireless network device moves, its distance from the locked-in access point used for network communication changes. If the roaming wireless network device moves far enough, it may be switched over to another access point which is now closer. For example, if the ambulatory patient carrying the vital signs transducer **18** moves away from the computer **30** (which embodies a software access point) and toward the access point **24**, eventually its wireless network connection will switch over to the access point **24**. Thus, the wireless network inherently includes the capability of performing a rough tracking of roaming network devices. The wireless network devices tracking system **38** more precisely determines the location of each wireless network device **12**, **14**, **16**, **18** based on factors such as signal strength, triangulation of the signals received by several access points, or so forth. The wireless network devices tracking system **38** is limited to tracking network devices **12**, **14**, **16**, **18** which are connected with the medical facility network **10**.

With continuing reference to FIGURES 1 and 2, not all wireless devices are network devices connected with the medical facility network **10**. For example, local wireless devices **50**, **51**, **52** may include local wireless capability that is not compatible with the 802.11 wireless protocol or other wireless network protocol employed by the medical facility network **10**. As illustrated in FIGURE 2, the local wireless device **50** is an infusion pump controlling an intravenous flow. The infusion pump **50** is wirelessly connected with the IV flow controller **14** which controls the infusion pump **50** to set the rate of intravenous infusion. The local wireless device **51** is a cellular telephone carried by a doctor or other medical person.

In some cases, the local wireless device can be an autonomous sensor network. For example, an autonomous vital signs sensor network **52** includes wireless sensors monitoring a patient's electrocardiograph (ECG), pulse rate, blood oxygen, and so forth. The vital signs monitor station **12** receives and displays the vital signs measured by the vital signs sensor network **52**; however, the vital signs sensor network **52** is autonomous

and continues to monitor the vital signs of the patient even if the patient is taken outside of radio range of the monitor station **12**, for example to be taken to a diagnostic imaging facility. Other examples of wireless devices that may be present in medical facility settings include wireless patient and staff identification bracelets or tags that include short-range wireless transmitters that identify the patient or staff member to local monitors.

The local wireless devices **50**, **51**, **52** employ a non-network wireless communication protocol such as an IEEE 802.15.1 protocol (also sometimes called Bluetooth) , an IEEE 802.15.3 protocol, an 802.15.4 protocol (also sometimes called ZigBee), or the like. Bluetooth, ZigBee, and most other short-range wireless communication protocols are incompatible with the 802.11 network protocol and other wireless network protocols. (The cellular telephone **51** is a local wireless device insofar as it includes short-range wireless protocol capability such as Bluetooth or Zigbee. The cellular telephone **51** also inherently includes longer-range wireless transmission capability in order to communicate with the cellular telephone network; however, the cellular protocol generally is incompatible with the 802.11 network protocol and most other wireless network protocols, and so the cellular telephone **51** is not connected with the wireless medical facility network **10**.) However, the local wireless devices **50**, **51**, **52** can communicate with each other when the distance between devices is within the short range of the local wireless communication capability, which is typically less than ten meters.

To locate these non-network local wireless devices **50**, **51**, **52**, the network devices **12**, **14**, **16**, **18**, and optionally also other non-network local wireless devices, are used. In addition to being wirelessly connected with the medical facility network **10**, many of these network devices include Bluetooth, ZigBee, or other non-network wireless connectivity, and various such network devices are generally present throughout the medical facility. Accordingly, each network device **12**, **14**, **16**, **18** having the requisite non-network local wireless communication capability performs occasional scans to detect local wireless devices within range that are also capable of communicating by the non-network local wireless communication protocol. In the illustrated configuration, the vital signs monitor station **12** detects the vital signs sensor array **52**. The IV flow controller **14** detects both the infusion pump **50** and the cellular telephone **51**. The nurses' station monitor **16** detects only the cellular telephone **51**. The vital signs transducer **18** does not detect any of the local wireless devices **50**, **51**, **52**. Because Bluetooth, ZigBee, and other non-network local

wireless communication protocols are short-range, only nearby network devices are able to detect a given local wireless device. Moreover, some network devices may not have the capability to communicate using the requisite non-network local wireless communication protocol, and thus cannot detect even nearby local wireless devices.

The non-network local wireless communications are indicated in FIGURES 1 and 2 by jagged connectors **54**, **55**, **56**, **58** drawn using dashed lines. Wireless communication **54** is between the nurses' station monitor **16** and the cellular telephone **52**. Wireless communication **55** is between the vital signs monitor station **12** and the sensors network **52**. Wireless communication **56** is between the IV flow controller **14** and the cellular telephone **52**. Wireless communication **58** is between the infusion pump **50** and the IV flow controller **14**. These Bluetooth, ZigBee, or other local wireless communications **54**, **55**, **56**, **58** are to be distinguished from wireless network connections following the 802.11 protocol or another wireless network protocol, such as the wireless network connection **36**, which are indicated by jagged connectors drawn using solid lines. Moreover, it is to be appreciated that the illustrated local wireless communications **54**, **55**, **56**, **58** are a snapshot in time – as devices move about, communications may be dropped as communicating devices move apart from one another, or added as devices capable of local wireless communication come together.

As illustrated in FIGURES 1 and 2, some local wireless communications **54**, **56** are brief polling communications limited to detecting and identifying local wireless devices within range. These are typically not considered to be wireless connections, but rather are brief wireless polling communications. On the other hand, in some cases a network device may actually be wirelessly connected with a local wireless device for the purpose of substantive transmission of data, control commands, or the like. In FIGURES 1 and 2, two example wireless connections are: (i) the local wireless communication **58** between the infusion pump **50** and the IV flow controller **14**; and (ii) the local wireless communication **55** between the autonomous vital signs sensors network **52** and the vital signs monitor station **12**. The substantive and prolonged nature of these local wireless connections **55**, **58** are indicated by filling the corresponding jagged connectors with a dotted pattern in FIGURES 1 and 2.

When nearby network devices **12**, **14**, **16** detect local wireless devices **50**, **51**, **52**, they communicate information about the detected local wireless devices to a derived

positions manager **60**. Typically, the communicated information includes an identification of the local wireless devices **50**, **51**, **52**, which may for example be a media access control (MAC) address for each detected local wireless device. Optionally, an indication of the signal strength of the local wireless communication **54**, **55**, **56**, **58** is also communicated. Based on the local wireless communication **54**, **55**, **56**, **58** and information indicative of the location of the detecting nearby network devices **14**, **16**, the location of the detected local wireless devices **50**, **51**, **52** can be estimated. Optionally, local wireless communication between two or more of the local wireless devices **50**, **51**, **52** (not illustrated) can also be used to aid in the locating.

Location information for roaming wireless network devices is suitably obtained from the network devices tracking system **38**. In a medical facility employing a mostly wireless network infrastructure, the tracked wireless network devices may be sufficient to perform locating of the local wireless devices. On the other hand, if there are a significant number of wired network devices that are generally stationary, the location of these stationary network devices is optionally also retrieved from a data file into which location information for stationary network devices has been previously entered. In this case, those stationary network devices which include Bluetooth, ZigBee, or another local wireless communication capability can also be used for detecting and localizing local wireless devices. The derived positions manager **60** estimates the location of detected local wireless devices **50**, **51**, **52** based on the locations of the nearby detecting network devices **12**, **14**, **16** using any suitable locating method. Other *a priori* knowledge, such as room layouts, last known position and device portability, nature of the device (i.e., sensors **52** that remain associated with the same patient), and the like can also be used by the derived positions manager **60** in locating the local wireless devices.

With reference to FIGURE 3, one suitable method for estimating the location of a local wireless device based on local wireless communication is described. Specifically, the location of the cellular telephone **52** is estimated based on the local wireless communications **54**, **56**. The local wireless communication **54** between the cellular telephone **52** and the nurses' station monitor **16** is achieved using: (i) local wireless communication hardware **64** installed in or integrated with the cellular telephone **52** employing a selected non-network local wireless communication protocol such as Bluetooth or ZigBee; and (ii) local non-network wireless communication hardware **66**

installed in or integrated with the nurses' station monitor **16** employing the same selected non-network local wireless communication protocol. Similarly, the local wireless communication **56** between the cellular telephone **52** and the IV flow controller **14** is achieved using: (i) the local wireless communication hardware **64** of the cellular telephone **52**; and (ii) local non-network wireless communication hardware **68** installed in or integrated with the IV flow controller **14** employing the same selected non-network local wireless communication protocol. In FIGURE 3, all three local non-network wireless communication hardware components **64**, **66**, **68** are Bluetooth cards installed in the respective devices **52**, **16**, **14**.

In some embodiments, the derived positions manager **60** estimates the location of the local wireless cellular telephone **52** based on the signal strengths of the local wireless communications **54**, **56**. In the example illustrated in FIGURE 3, the signal strength of the local wireless communications **54** is substantially stronger than the signal strength of the local wireless communications **56**, as indicated diagrammatically by a thicker jagged connector representation of the wireless communication **54**. This stronger signal for the wireless communication **54** indicates that the distance between the cellular telephone **52** and the nurses' station monitor **16** is smaller than the distance between the cellular telephone **52** and the IV flow controller **14**. Accordingly, the cellular telephone **52** can be estimated to be relatively closer to the nurses' station monitor **16** and relatively further away from the IV flow controller **14**. In some embodiments, a more quantitative distance estimate is made, for example based on the assumption that the signal strength for an omni-directional wireless communication decreases proportional to the square of the distance from the signal source.

If the signal strength is not measured or is not communicated to the derived positions manager **60**, the distance between the local wireless device and a nearby detecting network device can be estimated as less than or about the maximum communication distance of the local wireless communication. This approach is simple and can be relatively accurate when the range of the local wireless communication is short. For example, Bluetooth and ZigBee devices typically have a communication range of about ten meters, enabling localization to within about ten meters by this method. If only a single network device detects the local wireless device, then it may be sufficient to estimate the location of the local wireless device as substantially coinciding with the location of the

detecting network device, which will be accurate to within about ten meters for typical Bluetooth and ZigBee communication ranges.

If a local wireless device is detected by more than one network device (such as the cellular telephone **52** being detected by two network devices **14**, **16**) then the combination can be analyzed to more closely estimate the location of the local wireless device. For example, a triangulation method can be employed, in which a circle or sphere around each network device is estimated having a radius corresponding to the determined distance between the network device and the local wireless device, and the intersection of the circles or spheres is the estimated location of the local wireless device.

In yet another approach by which the derived positions manager **60** can estimate the location of a detected local wireless device, if there is a substantive local wireless connection between the local wireless device and a network device, such as the illustrated local wireless connections **55**, **58**, then it is typically reasonable to assume that the local wireless device is in the same room as the connected network device. For example, it is highly likely that the vital signs sensor network **52** is in the same room as the vital signs monitor station **12** when the sensor network **52** is wirelessly connected with the monitor station **12** to perform vital signs monitoring of a patient.

With reference to FIGURE 4, in one suitable embodiment a client program **70** is installed on each of the network devices **12**, **14**, **16**, **18** that includes the capability to communicate using the Bluetooth, ZigBee, or other local wireless communication protocol. The client program **70** performs operations that scan for local wireless devices and communicate detection of such devices to the derived positions manager **60**. In an operation **72**, the client program **70** causes the network device to employ the Bluetooth, ZigBee, or other selected non-network local wireless communication protocol to scan for other devices having the requisite Bluetooth, ZigBee, or other local wireless communication capability. The detection results are compared with previous detection results stored in a local memory **74** on the network device in a comparison process operation **80**. In the illustrated example, the local memory **74** stores a device identification, such as a MAC address, and the signal strength of the local wireless communication for each detected local wireless device. The comparison process operation **80** detects addition of a new local wireless device (possibly indicating that a roaming local wireless device has moved into range), disappearance of a previously detected local wireless device (possibly

indicating that the roaming local wireless device has moved out of range), or a change in the signal strength of the local wireless communication (possibly indicating movement of the local wireless device). If a change is detected, the derived positions manager **60** is notified of the change in operation **82**, and the local memory **74** is updated in operation **84**. After a delay **86**, the process operations **72**, **80**, **82**, **84** are repeated. In this way, any change in the detection status of any local wireless device within the range of the network device is timely reported via wireless connection to the derived positions manager **60**; however, when nothing has changed, no wireless network communication traffic is generated.

The use of the client program **70** installed on each of the network devices **12**, **14**, **16**, **18** advantageously reduces wireless network traffic and can speed up the local wireless polling operation **72**. However, in some other contemplated embodiments the derived positions manager performs centralized polling by individually commanding each network device to perform polling and report results to the derived positions manager. The derived positions manager performs the change detection based on the data received from the network device. These embodiments do not require installing remote client software on the network devices.

With returning reference to FIGURE 1, the location information can be provided to the user in any suitable manner. In some embodiments, a digital hospital map **90** is accessed via the local area network **10** and displayed on the computer **30** or on another display device. The location of each detected local wireless device estimated by the derived positions manager **60** is suitably superimposed on the displayed hospital map. Instead of or in addition to such a graphical representation, the information can be listed; for example, each local wireless device can be listed along with the room in which that device is disposed. Moreover, optionally the locations of wireless network devices determined by the network devices tracking system **38** is integrated with the locations of the local wireless devices to generate an integrated database of device locations that can be mapped or otherwise displayed.

Relating a location to the digital hospital map **90** can also be used to determine which room of the medical facility contains the location. This type of analysis can be used by the derived positions manager **60** to determine which room contains the nearby network devices detecting a particular local wireless device. If all the detecting nearby network

devices are in the same room, the local wireless device is suitably estimated to also be located in that room. Similarly, where a local wireless device has an established local wireless connection with a network device, the room containing the connected network device is also generally a good estimate of the location of the wirelessly connected local wireless device.

The invention has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.